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HANDBOOK

OF THE

RANGE-FINDER INFANTRY No.12

(Marks III, III**, IV, IV*, IV**, and V)

1933

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By Command of the Army Council,

H. J. Creedy

THE WAR OFFICE,
31*st July*, 1933.

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CHAPTER I

THE COINCIDENCE RANGE-FINDER

A.—The Range-finding Principle

Coincidence range-finding depends upon the principle that the *angle* subtended at a distant object by a fixed length and the *distance* between the object and the fixed length are directly related.

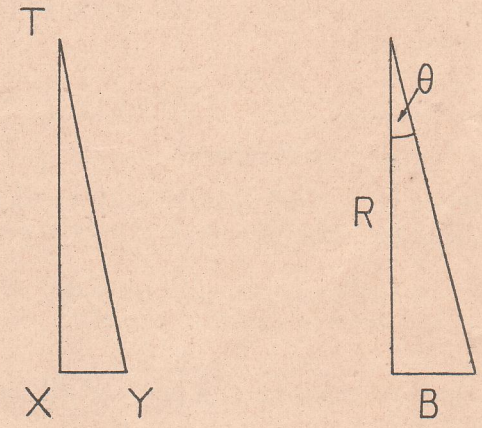


Fig. 1.

If T represents a distant object to which the range XT is required, and XY is a fixed length which can be maintained at right angles to XT, it can be seen that for any definite range XT there will be a definite angle XYT, so that it should be possible to determine the range by measurement of this angle.

Finding this angle XYT is equivalent to finding the angle XTY, as they are together equal to 90°. The angle XTY is the angle subtended by XY at the target T, and is usually called the "*apex angle.*"

The coincidence range-finder is so designed that on directing the instrument towards a distant object two images of the object are seen through the eyepiece. These are formed by rays from the object which are reflected at both ends of the "base" of the instrument (represented in the diagram by XY). The operation of bringing these images into alignment or "making coincidence"

measures the apex angle XTY, and consequently determines the range.

Let the range be denoted by R,
the apex angle by θ,
and the base by B.

As the base is small compared with the range, the apex angle will be small, and

$$\frac{B}{R} = \theta$$

where θ is in circular measure. (Note 1.)

This is the fundamental formula of coincidence range-finding, and it should be noted that as B is constant, θ varies inversely with R.

The Range-finder No. 12 has a base of 80 cms. or 0.875 yards. and the shortest range measured is 250 yards, so that the largest apex angle is given by—

$$\theta = \frac{0{\cdot}875}{250} \text{ radians}$$

$$= 12 \text{ minutes.}$$

It can therefore be realized that, as such small angles are used to determine the range, great accuracy of measurement of angle is required.

Small errors in the measurement, however, are unavoidable, and it is convenient here to consider the effect of such errors on the range.

Let $d\theta$ be a small variation or error in θ, and dR the corresponding variation or error in R.

It can be deduced from $\theta = \frac{B}{R}$ that—

$$d\theta = \frac{B}{R^2} dR \text{ (where B is constant)}$$

or

$$dR = \frac{R^2}{B} d\theta \text{ (Note 2) ;}$$

i.e. for any given error $d\theta$ in the measurement of θ, the corresponding error in R, dR, varies as the square of the range R.

For example, if the error in range at 2,000 yards, due to a given error in θ, is 14 yards, at double the range (4,000 yards) the error will be four times as great, *i.e.* 56 yards.

This is illustrated by Fig. 2, which shows—

(i) The curve obtained by plotting $\theta = \frac{B}{R}$, where B = 0·875 yards, for values of R from 250 yards to 2,000 yards.

(ii) 10 seconds variation in θ, where R = 500^x, 1,000^x, 1,500^x. and the consequent variations in R.

R = 500^x		$dR = 13{\cdot}9^x$	
R = 1,000^x	(500 × 2)	$dR = 55{\cdot}6^x$	(13·9 × 4)
R = 1,500^x	(500 × 3)	$dR = 125^x$	(13·9 × 9)

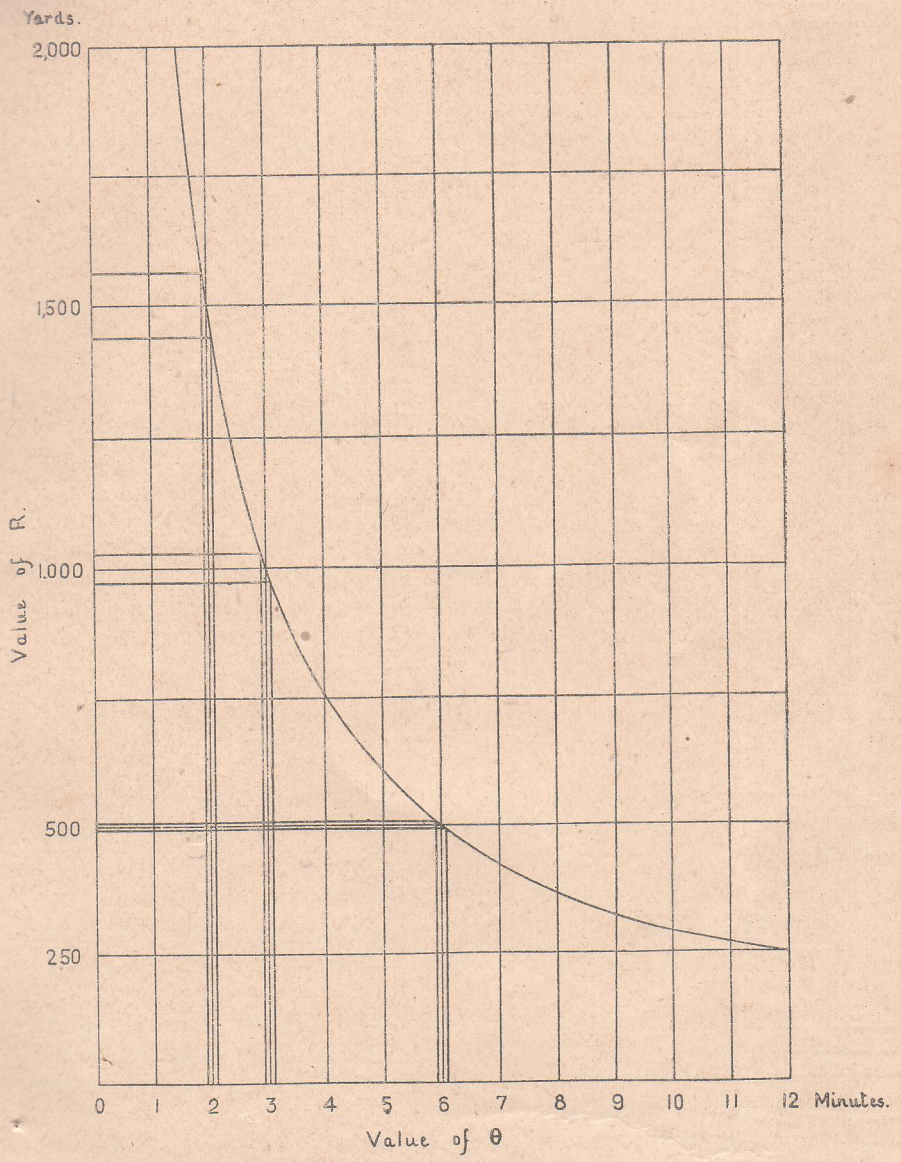


Fig. 2.

NOTE 1.—In circular measure the unit of angle is the " Radian." This is the angle subtended at the centre of a circle by an arc equal in length to the radius.

1 Radian = 57·3 degrees.
= 3,438 minutes.
= 206,265 seconds.

NOTE 2.—$\theta = \frac{B}{R}$

$\theta + d\theta = \frac{B}{R + dR}$, since $R + dR$ is the range corresponding to the apex angle $(\theta + d\theta)$.

Therefore, by subtraction,

$$d\theta = \frac{B}{R + dR} - \frac{B}{R}$$

$$= - \frac{B \,.\, dR}{R^2 + R \,.\, dR}$$

If dR is small compared with R, $R \,.\, dR$ may be neglected in comparison to R^2.

Therefore $$d\theta = - \frac{B \,.\, dR}{R^2}$$

The minus sign indicates that if dR is positive, *i.e.* an increase in R, $d\theta$ is negative, *i.e.* a decrease in θ; and *vice versa.*

B.—THE COINCIDENCE PRINCIPLE AND THE OPTICAL SYSTEM

Fig. 3 shows—

(i) Two similar convex lenses A B set up with their axes coinciding, the distances between the lenses being twice their focal length. (Note 3.)

(ii) A screen C interposed midway between A and B.

(iii) Two pentagonal prisms D E mounted outside the lenses so as to reflect rays from a distant object through the lenses. (Note 4.)

A point object is considered (*a*) at an infinite distance, (*b*) at a finite distance R, the object in each case being in such a direction that rays from it passing through D are reflected parallel to the common axis of A and B.

(Only those rays which pass through the centres of the lenses are shown in the diagram. These are called " principal rays." These rays are shown by chain dotted lines thus —·—·—. The rays are similarly marked in all other figures illustrating the action of the optical parts.)

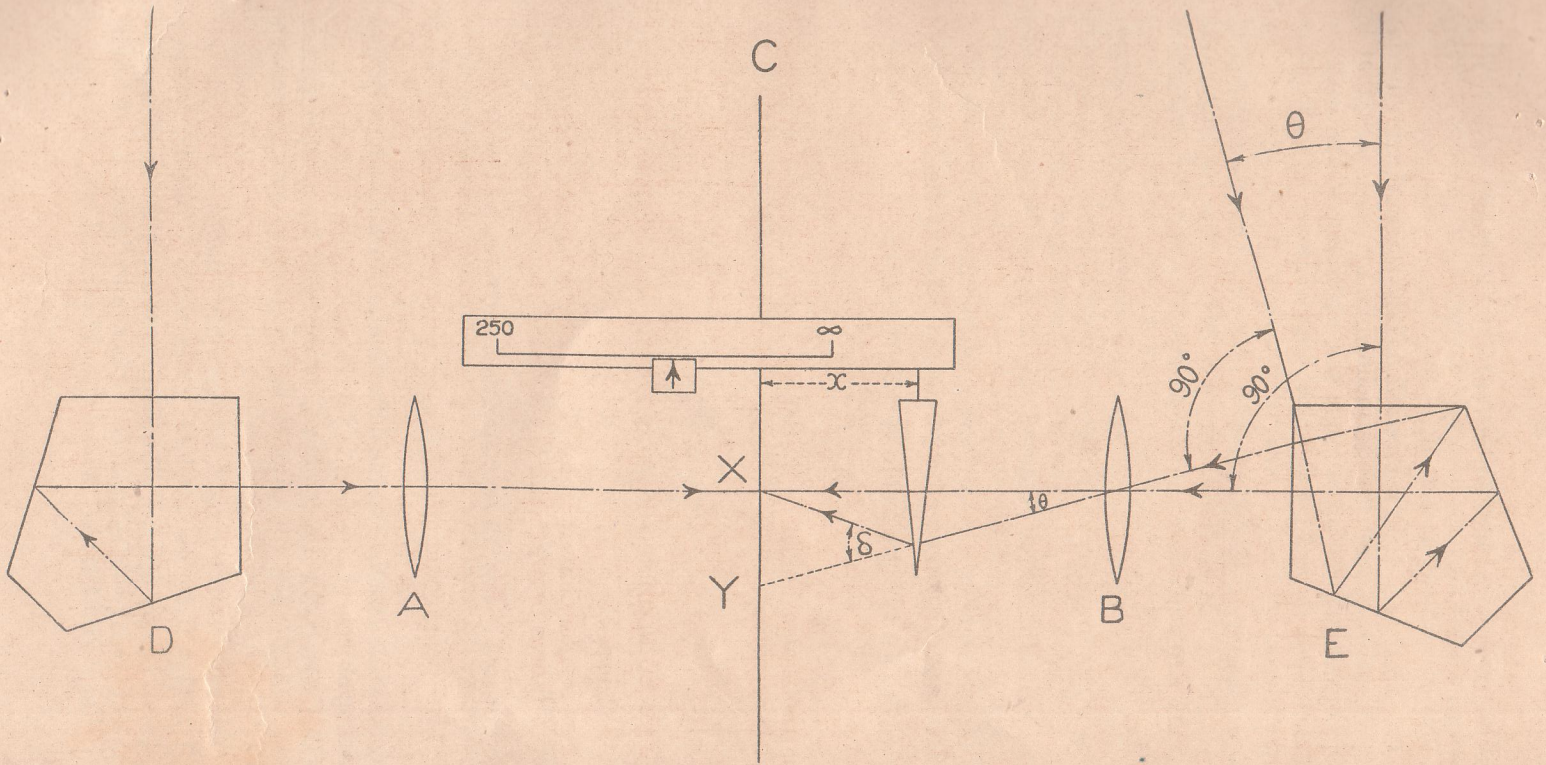


Fig. 3.

N.B.—The angles θ and δ are very much exaggerated in size.

(*a*) *The object at an infinite distance.*—The principal rays entering the pentagonals will be parallel, and coincident images of the object will be formed by the lenses at X.

(*b*) *The object at a finite distance R.*—The principal ray entering the right pentagonal will now be inclined at an angle θ to that in (*a*), this angle being the apex angle corresponding to the distance R, and the image formed by the right lens will now be at Y, while the image formed by the left lens will remain at X.

If a suitable small-angled prism is interposed between B and C, a position for it can be found where it deflects the rays from the right in such a manner that the image is now formed at X coincident with that formed by the left lens. (Note 5.)

For any value of R there will be a definite position of this deflecting prism to make the images coincident, so that if a suitable scale of ranges R be attached to the prism and coincidence of images of a distant object obtained, the range can be read from the scale against a fixed pointer.

Let the distance of the deflecting prism from the screen be x, the focal length of the lenses f, and the deviation of the prism δ.

The angles θ and δ are small, so we may write—

$$\theta = \frac{XY}{f}$$

$$\delta = \frac{XY}{x}$$

Hence $$x = \frac{f\theta}{\delta}$$

But $$\theta = \frac{B}{R}$$

Therefore $$x = \frac{fB}{\delta R}$$

Now f, B and δ may all be considered constant, so that—

$$x \propto \frac{1}{R}$$

Thus the scale attached to the deflecting prism will be a reciprocal scale of ranges.

In the range-finder the screen C is replaced by a combination of prisms, which cause the rays to be reflected in such a manner that—

(i) The rays from the right form an erect image.

(ii) The rays from the left form an inverted " mirror " image.

(iii) These images are not allowed to overlap, the line of separation being that edge of the upper prism marked " dividing line," and lettered A D in Fig. 11 (*a*) and (*c*).

(iv) These images are formed in a plane inclined at 30° to that of the range-finding triangle, so that they may be conveniently viewed by means of an eyepiece. The latter has a magnification of $\times 14$.

(v) This plane contains the dividing line, so that the images and the dividing line may be focussed simultaneously.

The action of the centre-prism combination is illustrated in Fig. 11 (Chap. II).

It would appear that the " infinity position " of the deflecting prism ($R = \infty$, $x = O$) will now be at the dividing line which is inside the centre-prism combination. This is avoided by an adjustment of the centre-prism combination which displaces the infinity position outside the prism. The adjustment, however, does not affect the graduation of the range scale.

Fig. 9, p. 16, shows diagrammatically the general arrangement of the optical system, the deflecting prism being placed to " make coincidence " on an object " at infinity."

The images of a distant object on which an adjusted instrument is directed will appear in the field of view as below.

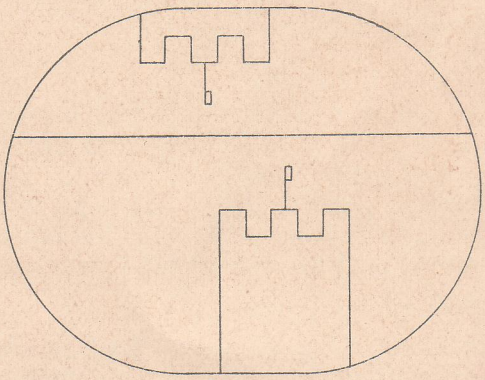


Fig. 4.

Depressing the instrument will cause the images to move towards the dividing line.

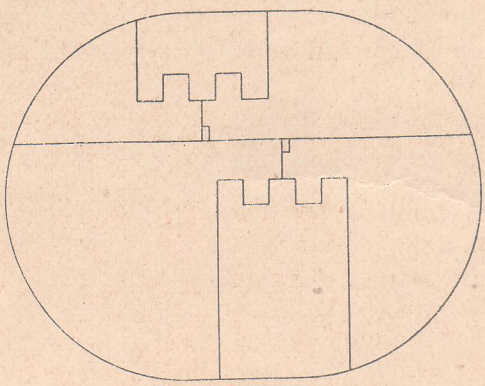


Fig. 5.

And by moving the deflecting prism the lower images may be brought into alignment with the upper.

This operation is called " making coincidence."

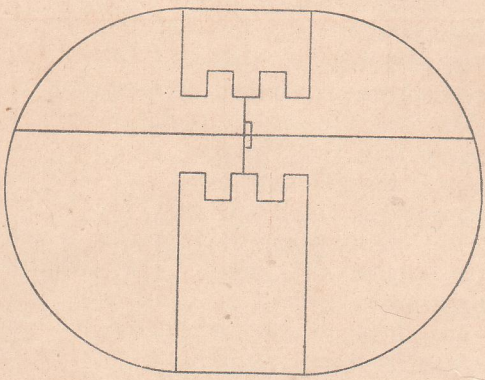


Fig. 6.

If the coincidence is exact, and the instrument is in exact adjustment, the range scale will indicate the range to the object (conditions of observation being normal).

NOTE 3.—CONVEX LENS.

This has the property of forming a true inverted image of a distant object in a plane at a fixed distance from the lens, the distance being called the " focal length " and the plane the " focal plane." The position of the image of any point of the object will be the intersection of the principal ray (*i.e.* the ray passing straight through the centre of the lens) and the focal plane.

NOTE 4.—PENTAGONAL PRISM.

Diagrams are given in Fig. 10, p. 18. Rays passing through the prism in a plane parallel to that of the section shown will be deviated through 90°, whatever the angle of incidence. Rotation of the prism in this plane will not alter the deviation.

Rotation about an axis PQ, however, will cause the emergent ray to be deviated up or down out of the plane containing the rays shown in Fig. 10 (*a*). This property is made use of in the " halving adjustment " (*see* pp. 17 and 32).

NOTE 5.—SMALL-ANGLED PRISM.

A small-angled prism has the property of deviating a ray of light through a constant angle, provided that the angle of incidence is not large.

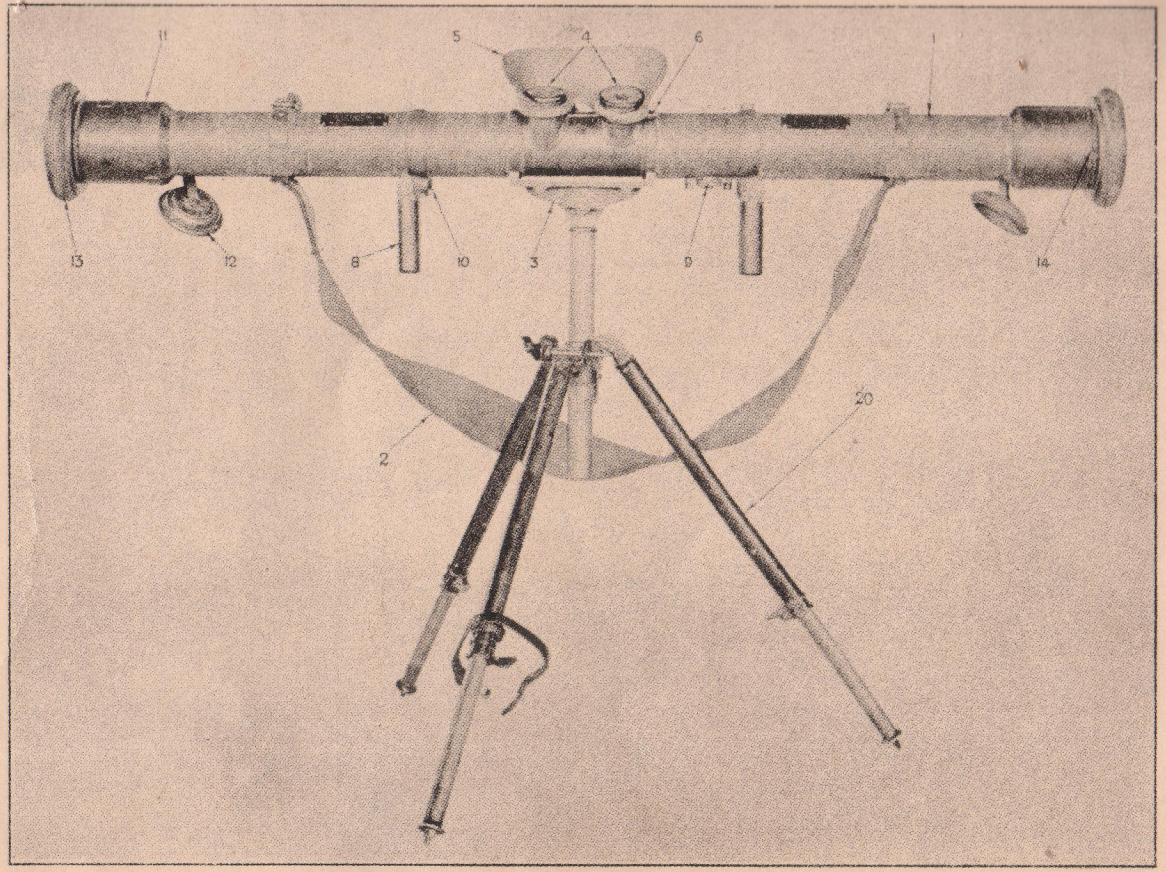


PLATE I.

PLATE II.

CHAPTER II

DESCRIPTION OF THE RANGE-FINDER AND ADJUNCTS

The instrument is officially known as the Range-finder No. 12, Marks III, III**, IV*, IV** and V. The Mark V is the latest service instrument, and is described in this chapter. The earlier marks are obsolescent. A list of the various earlier marks of No. 12 range-finder, with notes on their differences, is given in Appendix IV.

PARTICULARS OF THE RANGE-FINDER.

Length overall	35·75 inches.
Base length	80 cms. =31·5 inches.
Diameter of body...	2·22 inches.
Diameter over end caps	4·25 inches.
Weight of range-finder	10 lb. 6 oz.
Range scale graduated from 250 to 20,000 yards.	
Magnification	14 diameters.
Field of view, horizontal, upper	2 degrees 50 minutes.
,, ,, horizontal, lower...	3 degrees.
,, ,, vertical, upper	45 minutes.
,, ,, vertical, lower	1 degree 35 minutes.
Inclination of eyepieces to the horizontal ...	60 degrees.

The range-finder consists of two principal parts—the outer or main tube with the external arrangements, as given at A below, and the inner frame, containing most of the internal arrangements, as explained at B.

Plate I shows the instrument on its stand from the rear or range-taker's side, and Plate II from the front or target side. Plate III shows the general internal arrangements. Plate IV shows the instrument in its wooden case fitted with the lath adjusting and also in its web cover.

Fig. 9 shows diagrammatically the disposal of the optical parts and range scale in the outer tube and inner frame of the range-finder. The parts are numbered as in the plates.

A.—EXTERNAL ARRANGEMENTS

The principal external parts shown on Plates I and II are as follows :—

(1) Outer tube.
(2) Detachable web sling.
(3) Plate.

(4) Eyepieces, left and right.
(5) Detachable rubber facepiece, No. 1, Mark 1.
(6) Focussing lever.
(7) Front range scale window, No. 2, Mark I.
(8) Handles.
(9) Working head.
(10) Astigmatiser lever.
(11) Tube ends.
(12) Leather protecting caps.
(13) End cap.
(14) Locking pieces.
(15) Right window.
(16) Coincidence adjusting prism.
(17) Coincidence scale ring.
(18) Coincidence adjusting head.
(19) Halving adjusting head.

Outer tube (1).—The body of the range-finder consists of a steel tube about 34¼ inches long and 2¼ inches in diameter. This tube is covered with canvas painted service colour. This canvas tends to minimize distortion due to local heating by the sun.

Sewn on the canvas are fairways for the leather straps of the *web sling* (2).

Carrier Plate (3).—A carrier plate encircles the outer tube near the centre. It affords a means of attaching the range-finder to the stand, and is fitted with bearing rings, in which the range-finder can be rotated in such a manner that the line of sight is raised or lowered.

Eyepieces (4).—At the centre of the tube are the two eyepieces, which are surrounded by a *rubber facepiece* (5). They are inclined downwards at an angle of 60 degrees to the horizontal for the convenience of the range-taker. The right eyepiece is the one through which is seen the object to which the range is being taken. It is focussed by means of the small *focussing lever* (6). By moving this lever upwards the right eyepiece lenses are made to move slightly inwards towards the centre-prism combination. A revolving ring is mounted in the cap of the eyepiece. This ring is fitted with two glasses, one of which is clear and the other fieuzal, while a segment of the ring is left solid to protect the eyelens of the range-finder when the instrument is not in use. The ring can be turned by the action of the thumb on its milled edge, which projects through the underside of the cap. The coloured glass, termed a "*moderating glass*," is found to be of assistance when taking ranges in hazy or very bright weather. The left eyepiece is the one through which the range scale is seen. As the lens in it gives but slight magnification, no focussing arrangement is required. The left eyepiece is fitted with a revolving ring with a clear window, through which the range scale is viewed.

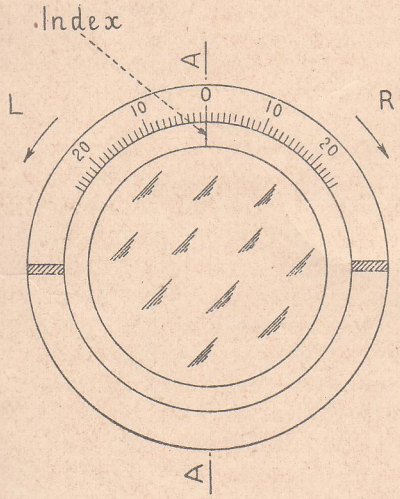
Front range-scale window No. 2, Mark I (7).—Above the left eyepiece, in front of the facepiece, is the front range-scale window for illuminating the range scale. It has a hinged metal cover to protect it. The range scale seen through this window is used when the ranges of moving targets are being taken or when testing range-takers, a second observer being detailed for reading the ranges.

Handles (8).—Beneath the range-finder, to the right and left of the eyepieces, are two folding handles, by means of which the range-finder is manipulated when fixed to the stand, or held when no stand is used.

Working head (9).—Near the right handle, underneath the tube, is the working head, by means of which the deflecting prism is moved in order to effect coincidence. Its position has been so arranged that it can conveniently be revolved by the thumb and forefinger of the right hand, whilst the remainder of the hand grips the handle.

Astigmatiser lever (10).—Near the left handle is the astigmatiser lever. When the lever is pushed up towards the main tube, the *astigmatisers* are brought into action (*see* p. 22).

Tube ends (11).—The ends of the outer tube are formed of hollow castings, slightly larger in diameter than the remainder of the tube. Circular openings are cut in these castings, and are fitted with glass



Front view.

Fig. 7.

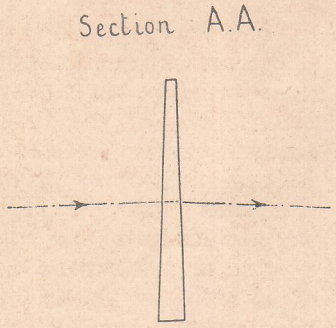
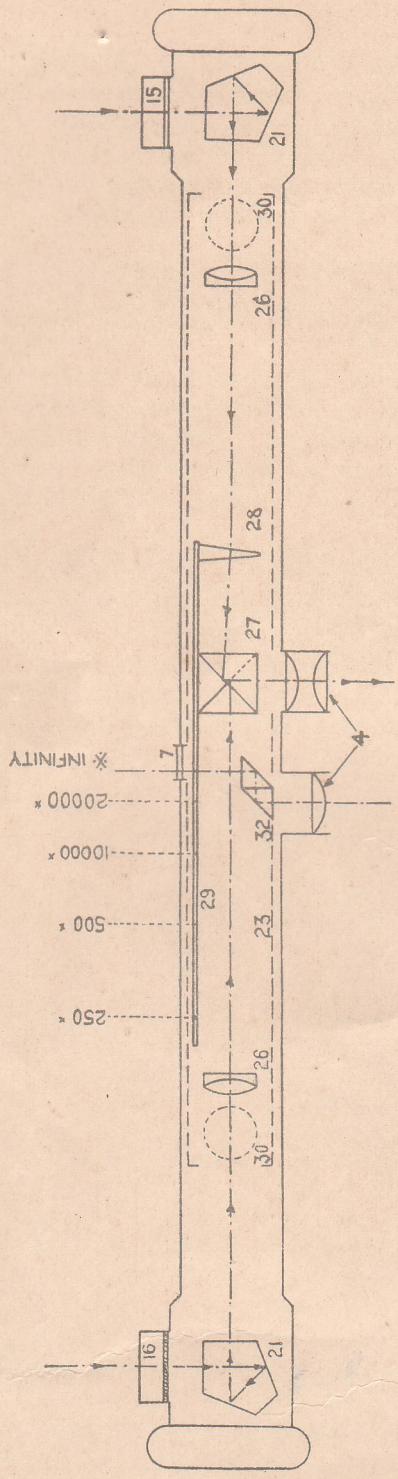


Fig. 8.

windows. The end castings contain the seatings for the pentagonal prism mounts.

Metal tubes with short *rayshades* are brazed over the hollow castings, and two hinged covers are fitted to the left tube end.



Diagrammatic elevation of object glasses with astigmatisers up in position.

FIG. 9

[To face page 17.]

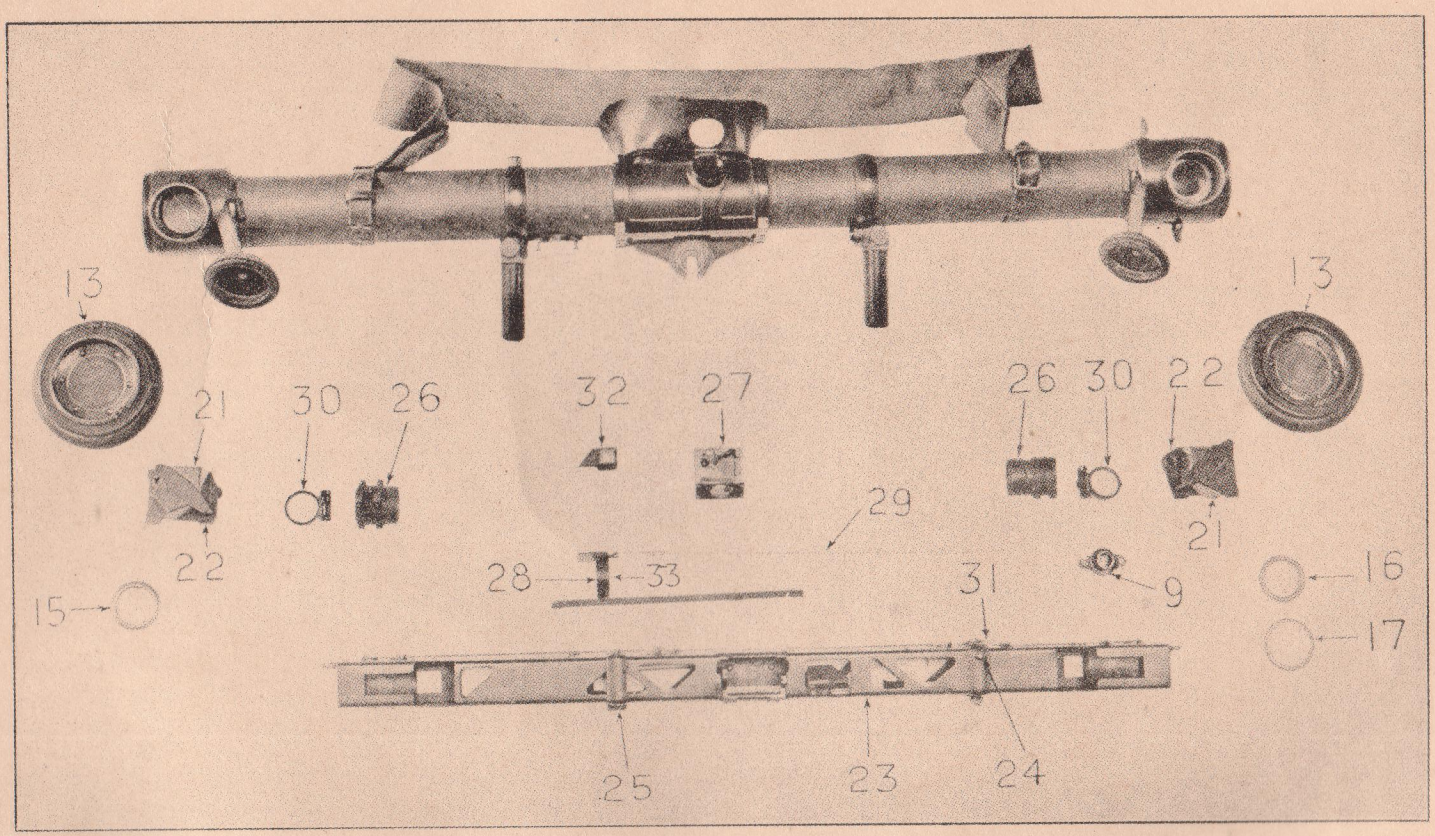


PLATE III. NOTE.—Inner frame (23) shown upside down to give a better view.

These covers protect the *coincidence* and *halving adjusting heads* (18), (19). *Leather protecting caps* (12) are fitted over the rayshades, and are attached to the tube ends by leather thongs.

End caps (13) *and locking piece* (14).—End caps, made of gun-metal, screw on to the tube ends. Each is fitted with a pad formed of a rubber ring, enclosed in canvas, for the protection of the range-finder. A small locking piece, kept in position by a screw, prevents a cap being unscrewed until the screw fixing the locking piece has been turned back a few turns, and the locking piece pushed into the recess in the tube end.

The right window (15).—This is a piece of parallel optical glass used to keep out dust and damp. It has no effect on the optics of the instrument.

Coincidence adjusting prism (16).—The left window consists of a deflecting prism of small angle (Figs. 7 and 8) to provide a means for the correction of errors in coincidence adjustment (*see* p. 34).

For this purpose it is mounted in a ring which can be rotated by the coincidence adjusting head.

A fixed scale, graduated as shown in Fig. 7, is engraved above the window, with an index on the revolving mount, for facilitating the coincidence adjustment.

Coincidence adjusting head (18).—This is carried on the top of the left end casting. It consists of a bevel wheel which is protected by a hinged cover. This bevel wheel is connected by means of spiral and spur gears to the cell of the left end window (or coincidence adjusting prism) in such a way that the latter revolves slowly when the bevel wheel is turned. Beneath the head is a spring clicker, which prevents accidental rotation due to vibration when travelling.

Halving adjusting head (19).—This is carried on the lower side of the left end casting, and consists of a bevel wheel which is covered in a similar manner to the coincidence adjusting head.

The halving head is geared with the left pentagonal prism in such a way that, when it is turned, the prism is rotated very slightly about the axis PQ (Fig. 10) (*see* p. 18). It has a clicker similar to that on the coincidence adjusting head.

B.—Internal Arrangements

Plate III shows the internal arrangements, which are numbered as below; the main or outer tube is also shown for the purpose of showing the relative sizes of the various parts. The positions of the optical parts in the assembled range-finder are best seen from Fig. 9.

(21) Pentagonal prisms.
(22) Pentagonal prism mount.
(23) Inner frame.

(24), (25) Inner frame supporting rings.
(26) Object glasses.
(27) Centre prism combination.
(28) Deflecting prism.
(29) Ivory range scale.
(30) Astigmatisers.
(31) Astigmatiser lever connector.
(32) Prisms for viewing range scale.
(33) Deflecting prism actuating rack.

Pentagonal prisms (21).—At each end of the range-finder is a pentagonal prism, the left-hand one of which is shown in Fig. 10 (*a*) in section in the plane of triangulation, and in Fig. 10 (*b*) in per-

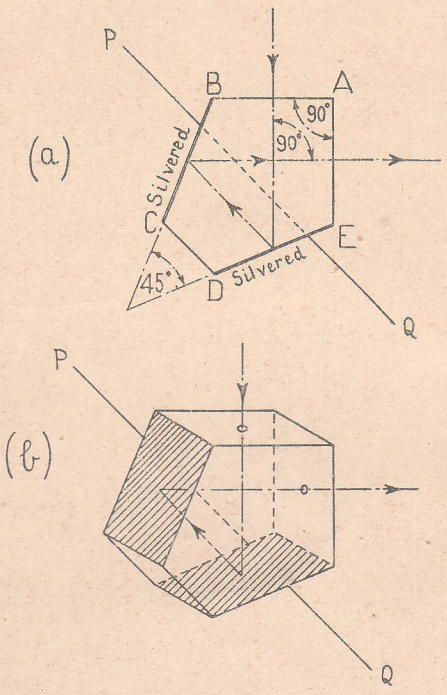


Fig. 10 (*a*) and (*b*).

spective. The prisms are mounted on metal *prism mounts* (22), having projections which can fit accurately into grooves in the end castings. The prisms can be adjusted with reference to the prism mounts. When the end caps are screwed home they press firmly against the prism mounts.

The two sides BC, DE of each prism are silvered and inclined to one another at 45 degrees. The faces BA and AE are inclined to one another at 90 degrees.

The left pentagonal is so mounted that by rotating the halving adjusting head it is turned very slightly about an axis PQ, which lies just beneath the prism.

Inner frame (23).—All the other main internal parts of the instrument are carried in the inner frame, which is a steel tube of square section, lightened by cutting away part of two of the sides. It is shown upside down in Plate III.

Inner frame supporting rings (24), (25).—Around the frame are two rings, which carry the fittings by which the inner frame is held in the main tube.

The left ring (24) carries at the top a spring plunger, and near the bottom two legs. These three fit in the smooth interior of the

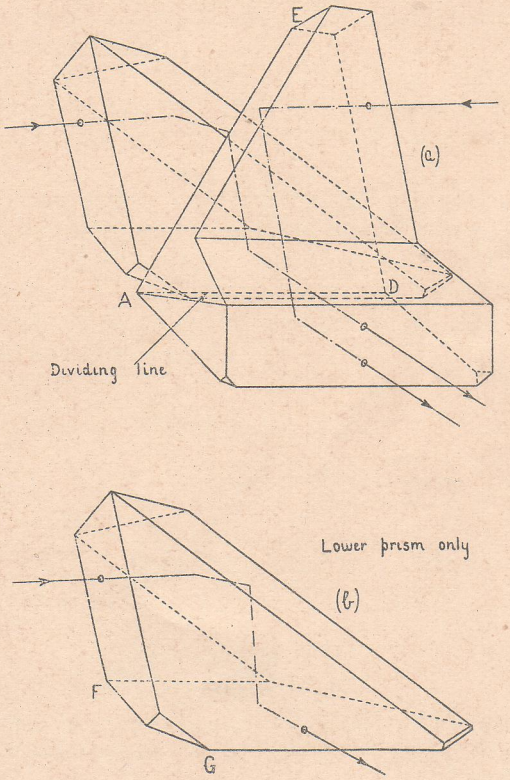


Fig. 11 (*a*) and (*b*).

outer tube, the plunger ensuring contact between the legs and tube.

The right ring (25) is constructed with a lengthwise slot at the top and a cylindrical hole at the bottom. Into these fit two ball-ended screws, passing through the outer tube.

It will be observed that the position of only one point on the inner frame, *i.e.* the centre of the cylindrical hole, is exactly fixed by the outer tube, and that the outer tube is able to bend, stretch and twist without communicating its distortion to the inner frame.

Object glasses (26).—An achromatic object glass is placed near each end of the inner frame.*

Centre prism combination (27).—In the centre of the inner frame, under the right eyepiece, is the centre prism combination. This consists of an upper and a lower prism securely held in a mount by screws and springs. The two prisms are not balsamed together, but

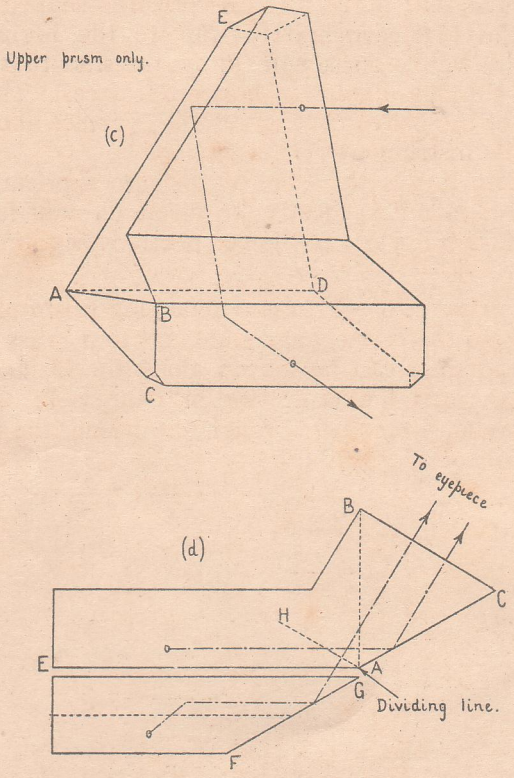


Fig. 11 (*c*) and (*d*).

are separated by an air space of approximately six thousandths of an inch. The upper prism is etched with two vertical lines and no prism surface is silvered.†

Fig. 11 (*a*) is a perspective diagram of the two prisms as seen from above and to the left, while Fig. 11 (*b*) and (*c*) give similar views of the two prisms separated. Fig. 11 (*d*) is a diagram of them as seen from the left.

---

* An achromatic lens is a combination of two lenses of different kinds of glass, so designed as to minimize colour defects.

† This type of centre prism combination was introduced in 1924, to replace balsamed and silvered prisms, which were not dependable in hot, damp climates, for they were liable to oxidation of the silver and deterioration of the balsam. The new centre prism combination will withstand rigorous climatic conditions and is designed to facilitate local cleaning.

The upper prism may be considered as a right-angled prism, used to reflect the light coming from the right of the instrument backwards, combined with an equilateral prism ABC, Fig. 11 (*d*), next used to reflect the light upwards, at 60° to the horizontal into the eyepiece.

The lower prism may be considered as a right-angled roof prism, used to reflect the light coming from the left of the instrument backwards. The rear portion of this prism is shaped with a slant face, FG, Fig. 11 (*d*), inclined at 30° to the horizontal, which next reflects the light up through the air space, so that it enters the upper prism through its lower horizontal face. Thus the light from the left of the instrument enters the eyepiece above that from the right of the instrument.

The dividing line is the edge of the upper prism in which its lower horizontal face EA, Fig. 11 (*d*), meets its slant face AC. The dividing line is marked AD in the perspective diagrams, Fig. 11 (*a*) and (*c*).

Deflecting prism (28).—This is a deflecting prism of small angle attached both to the ivory range scale and to a brass rack, so that both prism and scale can be moved along the inside of the inner frame by means of a pinion gearing into the rack. The pinion is fixed to a spindle, projecting through the frame, the spindle being rotated by the working head (9).

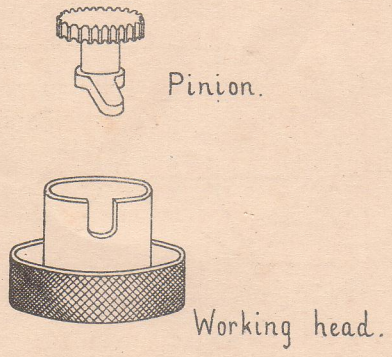


Fig. 12.

The arrangement shown in Fig. 12 ensures that any side force applied to the working head is taken by the outer tube. The centre portion of the working head is a hollow cylinder with a slot cut in its side. A lug on the spindle of the pinion fits loosely in this slot, enabling a twist of the working head to be transmitted to the pinion, but the inner frame cannot be distorted by forces applied to the working head.

Ivory range scale (29).—The range scale, engraved in black on both sides of a translucent ivory strip, can be seen through the front range-scale window No. 2 Mark I (7, Plate II).

It is a reciprocal scale of ranges, as explained on p. 10, and is graduated as follows :—

Section. yards.	Division. yards.	Numbered. yards.
250–500	10	every 10
500–1,000	10	,, 50
1,000–1,500	25	,, 100
1,500–2,000	50	,, 100
2,000–3,000	100	,, 500
3,000–5,000	100	,, 1,000
5,000–10,000	500	,, 5,000
10,000–20,000	5,000	,, 10,000

The scale being a reciprocal one, a short length of it represents a large difference in range at the higher ranges. Thus, to avoid the graduations being very close together at long ranges, it is necessary for the differences between the ranges marked by adjacent graduations to become larger as the range increases, *see* column headed "Division, yards" in the above table. Close to the 20,000-yard graduation on the scale is an infinity mark, denoted by an asterisk (*), on either side of which are three equally spaced graduations for use in correcting the coincidence adjustment of the instrument. These divisions are each of the same size as a 10-yard division at the 1,000 yard part of the scale.

Astigmatisers (30). — These cylindrical lenses * (Fig. 9) are hinged at the ends of the inner frame. They are placed in or out

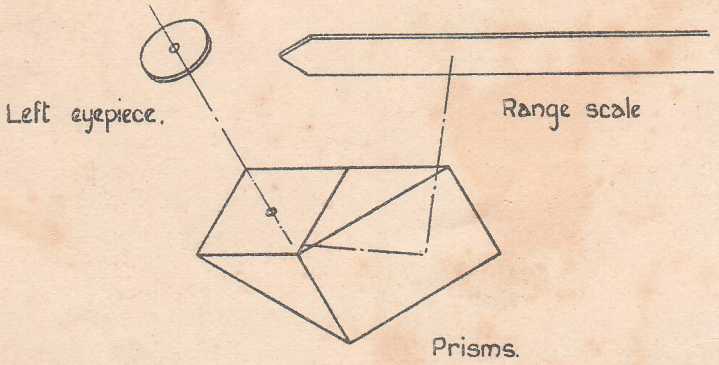


FIG. 13

of action by means of wires connected to a small forked *connector lever* (31), into which meshes the astigmatiser lever (10). The arrangement prevents the inner frame from being distorted by forces applied to the astigmatiser lever, *cf.* working head, above.

The image of any distant point formed by the combined action of an astigmatiser and object glass is drawn out into a short vertical

* Astigmatisers may be either plano-convex or plano-concave cylindrical lenses.

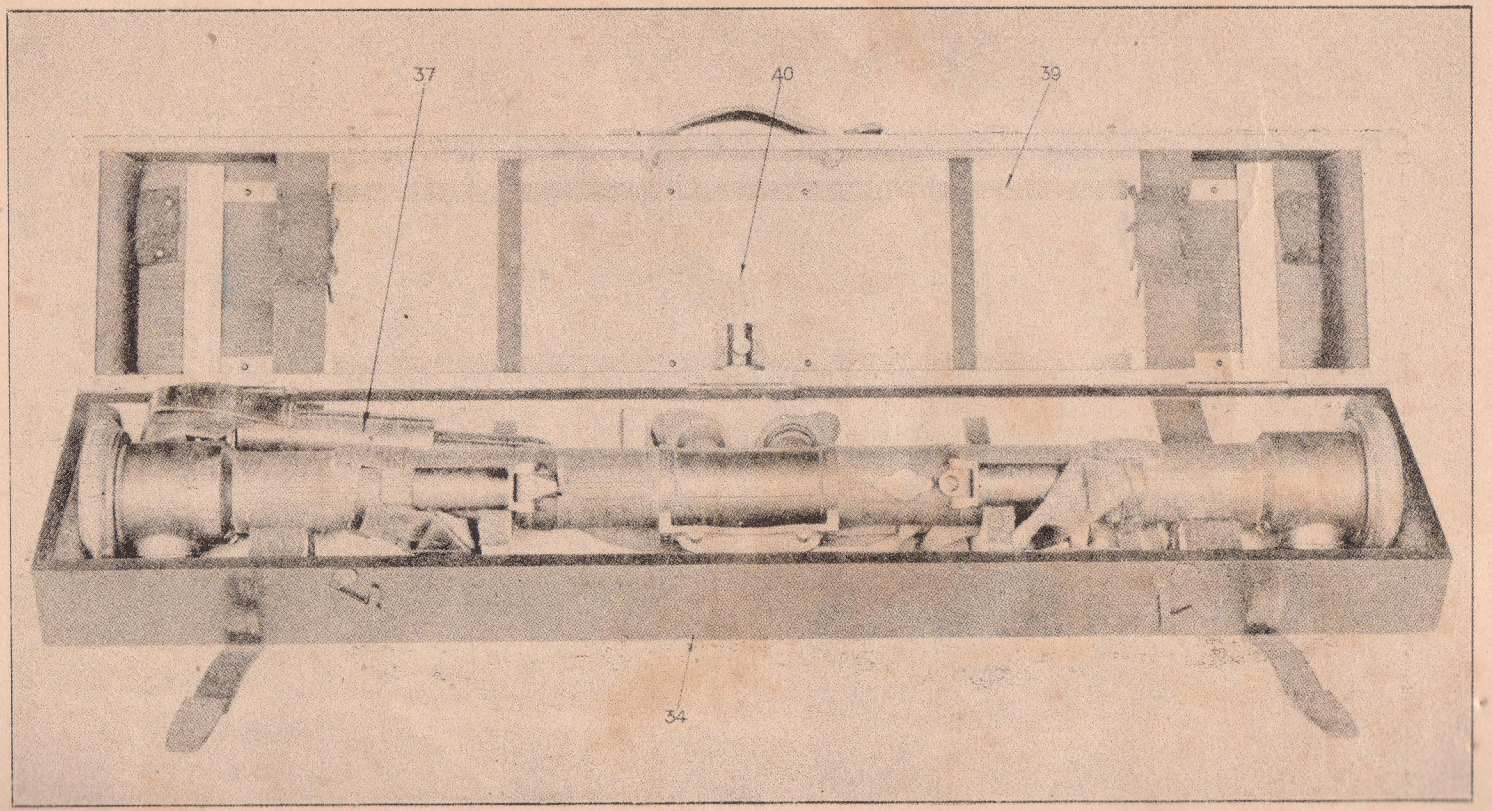


PLATE IV.

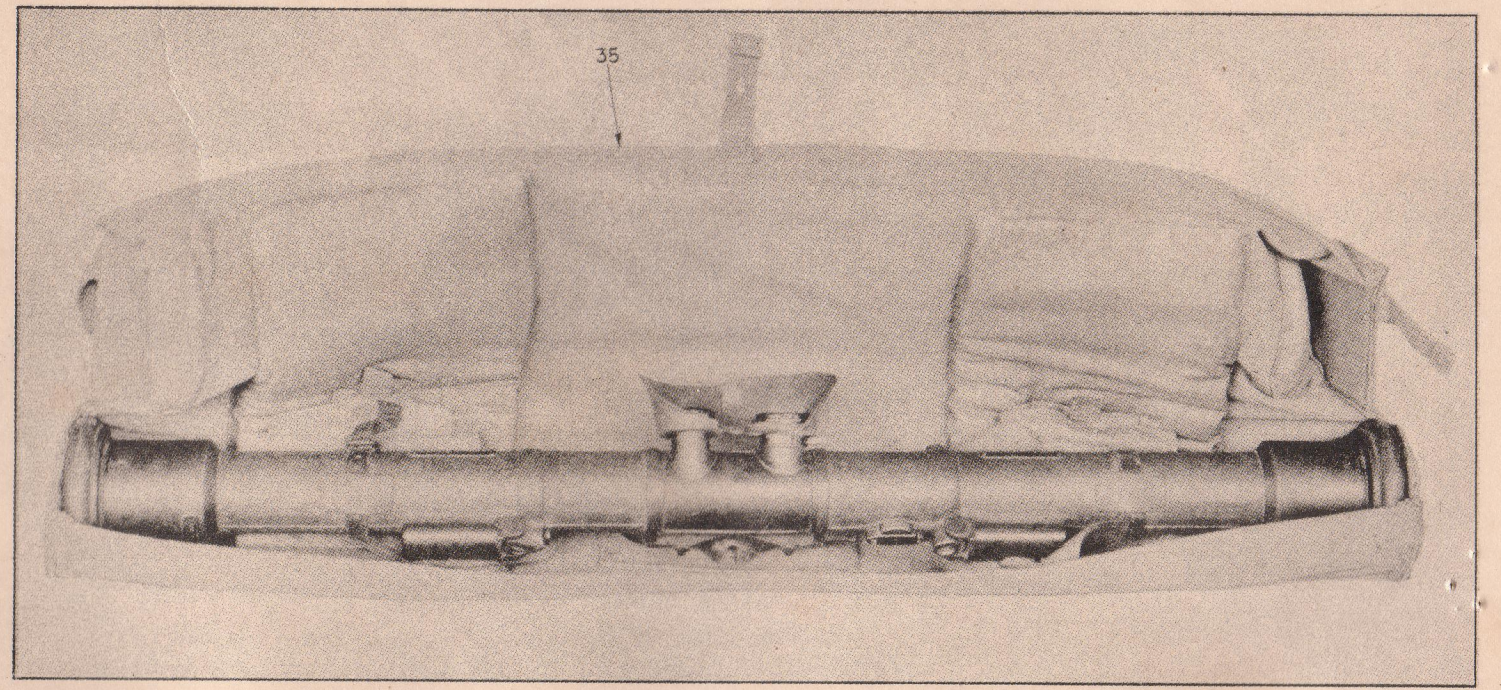


PLATE V.

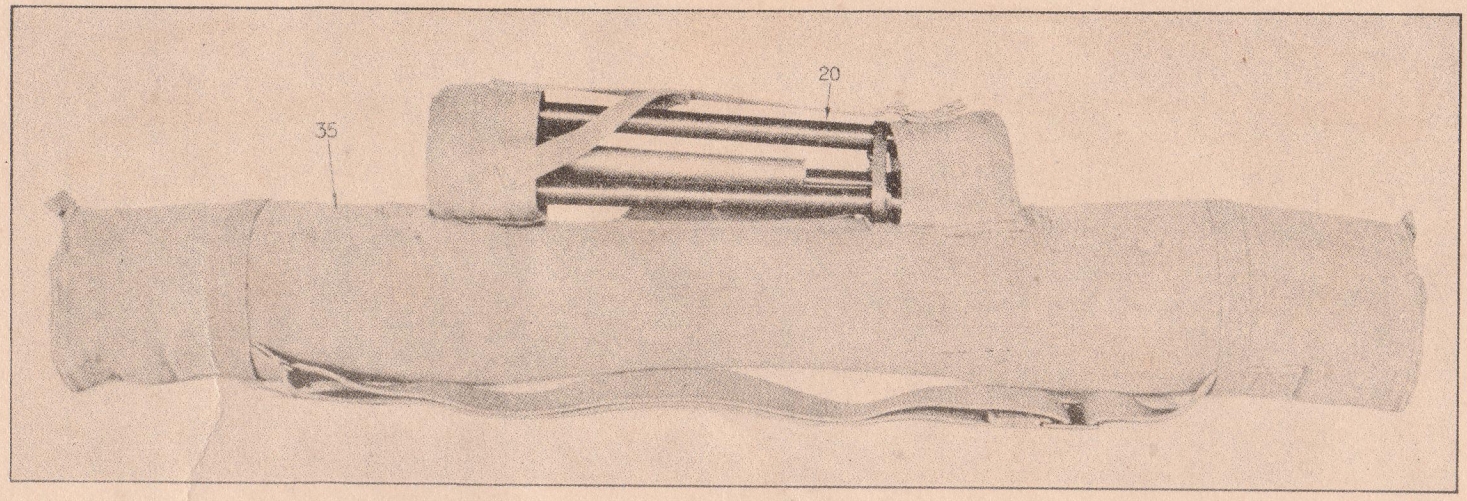


PLATE VI.

line. Thus, with the astigmatisers in action, *i.e.* as shown in the diagrammatic part elevations at the bottom of Fig. 9, each image in the field of view appears as a series of parallel vertical streaks. The astigmatisers are of use when taking ranges to a small, well-illuminated object, or for " coincidence adjustment " on a star.

Prisms for viewing range scale (32).—These two right-angled prisms are mounted on the inner frame, beneath the left eyepiece. They are arranged as shown in Fig. 13. The inner surface of the translucent range scale is thus seen through the left eyepiece, so that the scale appears to move vertically instead of horizontally.

C.—Adjuncts

The following stores, shown on Plate IV, V and VI, are issued separately for use with the range-fider. The latest patterns of these stores are described below, and where necessary earlier patterns are referred to in Appendix IV.

(34) Wooden case	16 lb.
(35) Canvas cover	4 lb.
(20, Plates I and II). Stand	3½ lb.
(37) Leather frog for stand	4 oz.

Case No. 12 *Range-finder, Mark IV; wood; with screw-driver and clip.*

The *case* (34) for range-finder is of wood, and is provided with internal fittings to hold the range-finder, and the *Mark II stand* (20) in its *frog* (37).

A metal *adjusting lath* (39) is secured to the inside of the lid of the case by means of four screws at the centre. Four end screws are screwed into the case through elongated slots in the lath, so as to allow for expansion of the metal. These end screws should never be screwed tight home. The lath has two white lines placed exactly 80 centimetres apart. These are used for testing the coincidence adjustment of the range-finder on an artificial infinity (*see* p. 37).

A *stay* (40) is fitted to the lid of the case to keep the lid in a vertical position whilst adjusting the range-finder by means of the lath. The stay is held in position by a plunger, and is drawn within the case when not in use.

A metal *clip* is attached to the front of the case to hold the screw-driver.

Cover, No. 12 *Range-finder, Mark IV*

The Mark IV *cover* (35) shown on Plates V and VI is of canvas web fitted with a web sling for carrying. It is well padded internally with felt, the pads being covered with canvas as a protection against moth. A hole is cut in each felt pad to receive a pocket, in which

cleaning materials may be carried, and a bucket is sewn to the exterior of the cover to accommodate the Mark III stand. The cover is fastened by means of straps, tabs and studs.

The Mark III* cover is similar to the Mark IV and is a conversion of the Mark III by the addition of a bucket to accommodate the Mark III stand.

The Marks II and II* covers are similar to the above but are of waterproof canvas with leather straps. The covers are provided with a small cylindrical box to accommodate a cleaning brush. The Mark II* is a conversion of the Mark II by the addition of a bucket to carry the Mark III stand.

Stand, Instruments, No. 14, *Mark III*

The *stand* (20) shown on Plates I and II consists of three telescopic legs hinged to a socket; the legs permit of adjustment of the stand for height. The socket is fitted with an extension tube which permits of adjustment of the instrument for height without disturbing the position of the stand, the tube being clamped at the desired height by means of a clamping screw.

A pivot, to which the carrier of the range-finder is attached, is supported in a bearing secured internally to the upper end of the extension tube and permits the range-finder being traversed in the horizontal plane.

Frog, No. 14 *Instruments Stand, Mark I.*

The frog is made of leather, and consists of a cylindrical leather body to take the Mark II stand, a cover to protect the head of the stand, and a loop at the back for attachment to a waistbelt.

CHAPTER III

RANGE-TAKING AND ANALYSIS

A.—RANGE-TAKING

Details of the use of the range-finder and the training of range-takers are given in the publication "Training in the use of the Infantry Range-finder, 1931," notified in Army Orders for July, 1931. A summary of the more important points to be observed in the use of the instrument is given below.

PRELIMINARY.

The windows and eyepieces of the range-finder should be clean, and the instrument should have been adjusted for coincidence by the range-taker who is about to use it (*see* p. 34).

Before the range-finder is used to take ranges, it must be—

(*a*) firmly set up on its stand, and (*b*) correctly adjusted for focussing and halving (*see* p. 32).

It is essential that the range-finder should be steady while coincidence is being made, and unless the focussing and halving are correct serious errors in coincidence may result.

MAKING COINCIDENCE.

There are two methods of making coincidence—

(*a*) The "alternate side" method; (*b*) the "breaking coincidence" method.

The first is used in all stages of training, while the second is only recommended for those *trained* range-takers who find that better results are obtained by its use.

(*a*) *The "alternate side" method.*—In all forms of coincidence observation there is a tendency on the part of the observer to judge the coincidence either consistently early or consistently late.

It is found, for example, that the mean of a series of observations taken with a "screwing-up" motion of the working head (*i.e.* bringing the lower image into coincidence with the upper by a right to left movement) differs from the mean of one taken with an unscrewing motion by more than is normally to be expected.

Errors due to this tendency may be eliminated to a large extent by making coincidence alternately from right and left in a series of observations, an even number being taken and the mean of these used as the final range.

(*b*) *The "breaking coincidence" method.*—A trained range-taker, when he has obtained approximate coincidence, can test it by turning the working head slightly in alternate directions. This breaks the coincidence on either side, and he gets an idea of the best central position to set the working head.

This method gives very good results with some range-takers, but many find the first method more satisfactory. In any case it should not be attempted until the man has attained sufficient experience to be able to judge his results by the two methods.

FURTHER POINTS OF IMPORTANCE WHEN RANGE-TAKING.

(*a*) Coincidence must be made in the centre of the field of view.

(*b*) The dividing line must be kept at right angles to whatever line of the object is used for coincidence (*see* p. 33).

(*c*) The most clearly defined line of the object should be used for coincidence, provided that it is vertical or nearly so. If there is no suitable line, coincidence may be made by symmetry of the images. The astigmatisers are often of use on a well-illuminated object.

(*d*) If possible, a series of observations not exceeding ten in number should be taken. Until the eye has accommodated itself to looking through the range-finder the observations may be erratic. The first observations may be neglected and more taken if this is apparent.

(*e*) Coincidence should be made quickly rather than slowly, thus avoiding strain to the eye. The experienced range-taker works quickly and accurately, whereas an inexpert man frequently makes a bad coincidence worse by spending too much time on it. If the eye tires rapidly, suspect the focussing adjustment.

(*f*) The front scale window should be shut when making coincidence. This not only ensures that the left eye is not distracted, but removes the possible bias caused by seeing the reading on the range scale too easily.

(*g*) A moderating glass is often of use under bright or hazy conditions.

(*h*) "Shimmer" may often be avoided by raising the range-finder off the ground, *e.g.* on to a wall.

(*i*) Tactical considerations must not be forgotten. It is most important to keep under cover as far as possible.

B.—THE ANALYSIS OF A SERIES OF OBSERVATIONS

EXACTNESS OF OBSERVATION.

It is stated in Chapter I that if the instrument is in exact adjustment, and exact coincidence obtained upon a distant object, the correct range would be indicated on the range scale under

normal conditions of observations. Unfortunately, it is not possible to realize this, the chief reason being that the eye is not able to appreciate exact coincidence.

It is found that the normal eye generally fails to detect a lack of coincidence between two lines as shown in Fig. 14, when the angle subtended at the eye by the lateral distance between the lines is less than about 12 seconds.

Thus in any apparent coincidence made by a range-taker, the

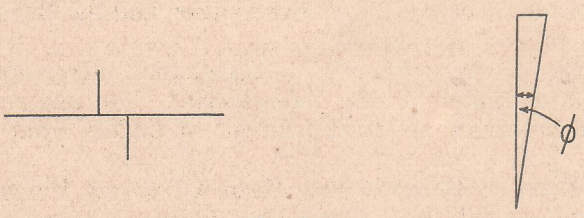


Fig. 14.

images may be separated by an angle ϕ, which could be represented as the angle subtended at the eye by the distance between two lines (Fig. 14).

Failure to make exact coincidence has the effect that there is an error in the apex angle measured, and consequently in the range.

This angular error ϕ is larger than the corresponding error in apex angle $d\theta$ in proportion to the magnification of the range-finder, so that if M is the magnification

$$\frac{\phi}{M} = d\theta.$$

Now, if $d\theta$ is an error in apex angle θ, the corresponding error in range is given by

$$dR = \frac{R^2}{B} d\theta \text{ (see p. 6).}$$

Combining these two formulæ

$$dR = \frac{R^2}{BM}\phi$$

This gives the relationship between an angular error in coincidence and the resulting error in range. The formula may also be written

$$\phi = \frac{BM}{R^2} dR.$$

As a result of the inability of the eye to appreciate exact coincidence, the observations of a series taken on a distant object will be found to differ, and some system of analysis is required to determine the best representative range of the series and to give some idea of its reliability.

The variations of the observations in coincidence range-finding follow the Law of Errors, and the analysis employed is based upon this law.

CALCULATION OF CONSISTENCY AND ACCURACY.

The mean of a series, obtained by dividing the sum of the observations by their number, is taken as the best representative range. It is called the "*Mean Observed Range.*"

The differences between each observation and the Mean Observed Range are called "*Residuals.*"

The mean of these differences—called the "*Mean Residual*"—is taken as an index of the "*Consistency*" or relative distribution of the observations (*cf.* the spread of bullets from a machine gun).

The difference between the Mean Observed Range and the True Range—called the "*Mean Deviation*"—is taken as an index of the "*Accuracy.*"

The chief factors affecting the Consistency are :—

(*a*) The skill of the observer.
(*b*) The mental and physical state of the observer.
(*c*) The conditions of observation.
(*d*) The nature of the target.

The accuracy is partly dependent on the consistency, and is therefore affected by the above factors. It is also affected by :—

(*a*) The coincidence adjustment.
(*b*) Variation of conditions since adjustment.
(*c*) The number of observations.

In general, not more than ten observations are used in any one series, as the time spent on taking more is not justified by the increase in accuracy obtained.

Examples are given below illustrating the determination of Mean Observed Range (M.O.R.), Mean Residual (M.R.), and (on page 31) Mean Deviation (M.D.).

Examples of Analysis.

Example 1.	*Observations.*	*Residuals.*
	2,730	30
	2,780	20
	2,760	0
	2,760	0
	2,780	20
	2,720	40
	2,800	40
	2,750	10
	2,750	10
	2,770	10
	27,600	180
	Mean observed range = 2,760^x	Mean residual = 18^x

Example 2.	2,900	100
	2,720	80
	2,630	170
	2,750	50
	2,800	0
	2,950	150
	2,840	40
	2,710	90
	2,830	30
	2,870	70
	28,000	780
	Mean observed range = 2,800x	Mean residual = 78x
Example 3.	1,035	6
	1,025	4
	1,030	1
	1,030	1
	1,020	9
	1,025	4
	1,030	1
	1,030	1
	1,025	4
	1,040	11
	10,290	42
	Mean observed range = 1,029x	Mean residual = 4·2x
Example 4.	1,005	6
	1,025	14
	1,020	9
	1,000	11
	1,030	19
	1,025	14
	1,000	11
	1,005	6
	1,010	1
	990	21
	10,110	112
	Mean observed range = 1,011x	Mean residual = 11·2x

CONSISTENCY AND CONSISTENCY FIGURE.

By means of the formula $\phi = -\frac{BM}{R^2}dR$ (p. 27) the residuals of a series may be expressed in terms of angular error in coincidence. The Mean Residual so expressed is termed the "*Consistency Figure.*"

It is found that a Consistency Figure of 12 seconds can easily be attained by a trained range-taker under normal conditions of observation.

Twelve seconds is accordingly taken as the *Standard for Consistency.*

It is convenient for purposes of comparison of Mean Residuals to employ a formula giving the Standard in yards. This formula is derived from the equation $dR = \frac{R^2}{BM}\phi$ (*see* p. 27) by substituting

$B = 0{\cdot}8752$ yards ;
$M = 14$;
$R = 1{,}000r$ (*i.e.* r = the number of thousands of yards in the range).

$$\phi = \pm\frac{12}{206{,}265} \text{ (12 seconds expressed in Radian Measure).}$$

Whence
$$dR = \pm\frac{1{,}000r \times 1{,}000r}{0{\cdot}8752 \times 14} \times \frac{12}{206{,}265}$$
$$= \pm 5r^2 \text{ yards.}$$

Thus the Standard for Consistency is 12 seconds angular error in coincidence, which is equivalent to $5r^2$ yards where r is the number of thousands of yards in the Mean Observed Range.

The range-taker's Consistency Figure is most easily obtained from the Mean Residual of his observations as follows.

$5r^2$ is equivalent to 12 seconds angular error in coincidence.

The Mean Residual is equivalent to $\frac{12}{5r^2} \times$ M.R. seconds angular error in coincidence.

i.e. Consistency Figure $= \frac{12}{5r^2} \times$ M.R. seconds.

Applying this to the examples given—

	M.O.R.	M.R.	$5r^2$	C.F.
Example 1.	$2{,}760^x$	18^x	39^x	$6''$
,, 2.	$2{,}800^x$	78^x	39^x	$24''$
,, 3.	$1{,}029^x$	$4{\cdot}2^x$	5^x	$10''$
,, 4.	$1{,}011^x$	$11{\cdot}2^x$	5^x	$27''$

It should be noted that, while the consistency of any one series can be judged by comparing the Mean Residual with $5r^2$, if series at different ranges have to be compared the Consistency Figures must be used, being independent of range. For following the progress of a range-taker, therefore, a record of Consistency Figures is kept in the form of a graph, known as the "*Progress Chart.*"

It must be emphasized that 12 seconds is only a standard for comparison, and in no way a limit which cannot be improved upon.

Many range-takers will work to Consistency Figures of 9 seconds and 6 seconds under normal conditions of observation.

ACCURACY AND ACCURACY FIGURE.

The Accuracy, as indicated by the Mean Deviation, was stated to be partly dependent upon the coincidence adjustment. This adjustment, moreover, is not stable, but liable to alteration with normal use. Some limit to the Mean Deviation must therefore be assigned, this limit indicating when further adjustment is necessary.

The range-finder is tested from time to time and adjusted if the Mean Deviation of the test series exceeds $5r^2$ (*see* pp. 34 to 38).

This must not be taken to imply that $5r^2$ is the maximum Mean Deviation to be expected, even with a freshly adjusted range-finder, but a Mean Deviation of less than $8r^2$ should be obtained by a trained range-taker under normal conditions, if he takes a series of 10 observations with an instrument he has recently adjusted.

The Mean Deviation may be expressed as an *Accuracy Figure* in the same manner as the Mean Residual was expressed as a Consistency Figure, *i.e.* Accuracy Figure

$$= \frac{12}{5r^2} \times \text{M.D.}$$

This accuracy figure (A.F.) may be recorded as a separate line on the Range-taker's Progress Chart.

Applying this to the examples on p. 28, the True Ranges (T.R.) being as given below—

	T.R.	M.O.R.	M.D.	A.F.
Example 1.	2,820	2,760	60^x	18″
,, 2.	2,820	2,800	20^x	6″
,, 3.	1,030	1,029	1^x	2″
,, 4.	1,030	1,011	19^x	4″

The Mark I range-taking calculator should be used for the above calculations.

CHAPTER IV

TESTS AND ADJUSTMENTS

A.—Preliminary Adjustments

Focussing.

The right eyepiece may be moved towards or away from the centre-prism combination by means of the focussing lever. This enables the range-taker to adjust the focussing to his own eyesight.

Procedure.—To adjust, direct the range-finder towards the sky and move the focussing lever until the dividing line appears clearly defined.

The instrument should now be in focus for objects at a distance greater than 200 yards. Care in focussing is important, otherwise consistent results cannot be expected, and the eye will rapidly become tired during range-taking.

Halving.

The left pentagonal is mounted in such a manner that turning the halving adjusting head causes it to be tilted, with the effect that the image seen in the upper field of view moves at right angles to the dividing line.

Procedure.—To test for halving, direct the range-finder at a flat-topped object and make approximate coincidence.

The dividing line should bisect the space between the two images of the object.

To adjust, uncover the halving adjusting head and turn it until the required position of the upper image is obtained.

Owing to the head being kept in position by a small spring plunger fitting into the serrations of the head, it may not be possible to obtain an exact adjustment.

Errors in halving may cause serious errors in coincidence if the dividing line is not at right angles to the line of the object used for coincidence.

An example of this is illustrated in Figs. 15 to 17. Fig. 15 shows approximate coincidence on a sloping post, the dividing line being horizontal and there being an appreciable error in halving (h).

If the range-finder is depressed to bring the two images together they will appear as in Fig. 16. There is now an apparent lack of coincidence. If coincidence is attempted by turning the working head and moving the lower image to the position shown in Fig. 17, there is considerable error, coincidence not being made between images of the same point on the object. The error in coincidence is the lateral distance (e).

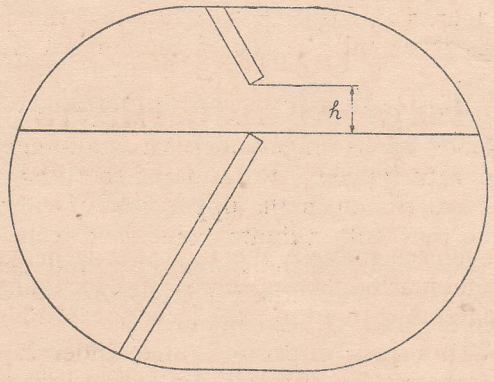


Fig. 15.

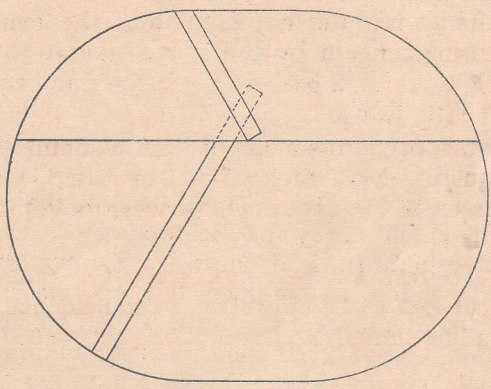


Fig. 16.

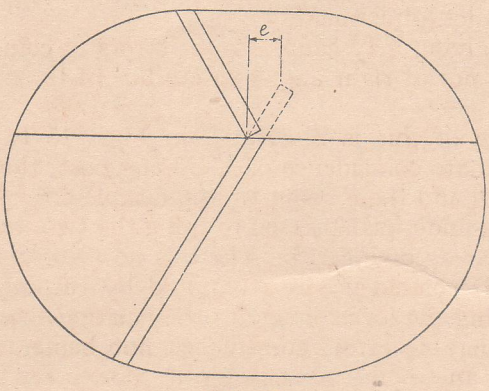


Fig. 17.

The dotted lines in Figs. 16 and 17 show the position of the lower image as it would be seen if the images were allowed to overlap.

B.—Adjustment for Coincidence

The left window of the range-finder is a small-angled prism which can be rotated with its cell. Rotation of the prism has the effect of causing the image seen in the upper field of view to move in a circular path, so that, within limits, coincidence can be obtained on an object independently of the range scale and deflecting prism. It is important to realize, however, that any movement of this prism will alter the halving adjustment.

The cell containing the prism is marked with an index line, which indicates the setting of the prism against a fixed scale (Fig. 7, p. 15).

There are three methods of coincidence adjustment, but the principle in each is the same.

The range-finder requires adjustment if the Mean Deviation of a reliable test series, taken by the range-taker who is to use the instrument, is greater than $5r^2$ when r is the number of thousands of yards in the True Range.

The Accuracy of any series is partly dependent on the Consistency, so that unless the Consistency of the test series is good, the test cannot be considered reliable. For this reason the Mean Residual of the test series should always be determined.

Moreover, if adjustment is attempted under conditions such that good Consistency cannot be obtained, not only may adjustment be difficult, but it may be inaccurate ; and it should be checked at the earliest opportunity when good conditions are obtainable.

It is essential that the range-taker who is to use the instrument should adjust it himself. Different range-takers will be found to have widely different adjustment settings on the same instrument.

An instrument once adjusted should remain in adjustment for a considerable period, provided it is not badly treated. It should, however, be tested from time to time.

The astigmatisers should be tested when coincidence adjustment is carried out (*see* p. 39).

Test and Adjustment for Coincidence on a "Known Range"

Requirements.—The "Known Range" must be accurately determined (maximum error r^2).

The object chosen should be easy for coincidence and well defined.

Procedure.—(*a*) *Test.*—Take a series of ten observations by means of the working head in the usual manner. If the Mean Deviation of the series is greater than $5r^2$ when r is the number of thousands of yards in the True Range, the range-finder requires adjustment.

(*b*) *Adjustment.*—Set the True Range on the range scale. Uncover the coincidence adjusting head and use it to take a series of ten observations, noting the readings on the scale of the left window.* Set the index line to the mean of these readings, and examine the range scale to see that it has not moved. Cover up the coincidence adjusting head. Adjust for halving if necessary.

Repeat the test as detailed at (*a*). If the Mean Deviation is still greater than $5r^2$, the adjustment must be repeated.

Example.—Known Range 2,042 yards.

(*a*) *Test.*	*Observations.*	*Residuals.*
	2,020	0
	2,050	30
	2,030	10
	2,000	20
	2,020	0
	2,030	10
	2,040	20
	2,010	10
	1,990	30
	2,010	10
	20,200	140

M.O.R. $= 2{,}020^x$ M.R. $= 14^x$
T.R. $= 2{,}042^x$ M.D. $= -22^x$
$5r^2 = 20^x$

The M.R. is less than $5r^2$, therefore the test is reliable.

The M.D. is greater than $5r^2$, therefore the instrument requires adjustment.

(*b*) *Adjustment.*	*Observations.*	
	Left.	*Right.*
	2·2	0·8
	2·0	—
	1·2	—
	1·4	—
	0·6	—
	1·8	—
	0·4	—
	1·2	—
	0·4	—
	11·2	0·8
	0·8	
	10)10·4	
	1·04	

The mean setting is 1·04 divisions Left.

---

* It is advantageous to have an assistant to read the coincidence adjusting scale (but not to manipulate the coincidence adjusting head). The observer is then less disturbed and the time taken over adjustment is much reduced.

Re-test.	*Observations.*	*Residuals.*
	2,040	0
	2,050	10
	2,030	10
	2,060	20
	2,020	20
	2,040	0
	2,030	10
	2,040	0
	2,060	20
	2,030	10
	20,400	100

M.O.R. $= 2{,}040^x$ M.R. $= 10^x$

T.R. $= 2{,}042^x$ M.D. $= -2^x$

$5r^2 = 20^x$

The M.R. is less than $5r^2$, therefore the test is reliable.
The M.D. is less than $5r^2$, therefore the instrument is in adjustment.

TEST AND ADJUSTMENT FOR COINCIDENCE ON A NATURAL INFINITY.

The range to the moon or the stars may be considered infinite as compared with the base length, and if coincidence is made on either, the range scale should read infinity.

The sun must not be used as a natural infinity, as damage may result both to the instrument and to the observer's eye.

The infinity mark is indicated by an asterisk, and there are three equal divisions + and —. These divisions are equal to a 10-yard division at 1,000 yards, so that the standard of accuracy, $5r^2$ is 0·5 division.

When adjustment is made using the moon, special care must be taken over the halving adjustment, as the moon's edge is circular and not straight. The halving adjustment may be conveniently carried out on the lower limb.

When the stars are used, the astigmatisers will have to be employed. Care should be taken that these are in adjustment.

Procedure.—(*a*) *Test.*—Take a series of ten observations with the working head, noting the readings + or — of the infinity mark. If the mean reading is greater than $\pm 0{\cdot}5$ of a division the instrument requires adjustment.

Example.
(*a*) *Test.*

Observations.		*Residuals.*
+	—	
1·1		0·5
1·0		0·4
0·8		0·2
0·6		—
1·0		0·4
0·4		0·2
1·0		0·4
	0·2	0·8
0·4		0·2
	0·1	0·7
6·3	0·3	3·8
−0·3		
6·0		

M.O.R. = + 0·6 divisions. M.R. = 0·38 divisions.
T.R. = 0 divisions. M.D. = 0·6 divisions.
$5r^2$ = 0·5 divisions.

The M.R. is less than $5r^2$, therefore the test is reliable.
The M.D. is greater than $5r^2$, therefore the instrument requires adjustment.

(*b*) *Adjustment.*—Set the range scale to read infinity. Uncover the coincidence adjusting head and use it to take a series of ten observations, noting the readings on the scale of the left-hand window. Set the index line to the mean of these readings and examine the range scale, to see that it has not moved. Cover up the coincidence adjusting head. Adjust for halving if necessary.

Repeat the test as detailed at (*a*). If the mean reading is still greater than 0·5 of a division, the adjustment must be repeated.

TEST AND ADJUSTMENT FOR COINCIDENCE ON AN ARTIFICIAL INFINITY.

A description of the lath adjusting is given on p. 23.

Theory.—If the lath is set up parallel to the range-finder at a short distance, and coincidence is obtained between the left mark in the upper field and the right mark in the lower field (Fig. 18), the range scale should read infinity.

This may be seen from Figs. 18 and 19.

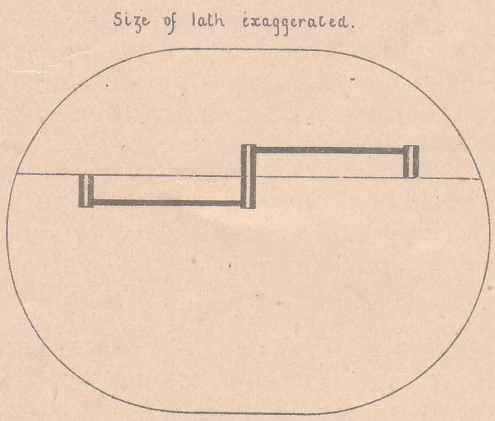


Fig. 18.

In the latter figure XY represents the base of the range-finder, and MN the marks on the lath.

When coincidence is obtained as above, MXY is a right angle, and MX, NY will represent the " principal " rays entering the left and right windows respectively.

As XY = MN, XYNM will be a rectangle, and MX will be parallel to NY.

This corresponds to an apex angle of 0, and therefore to an infinite range.

Remarks.—Errors due to a difference in length between the lath and the base of the instrument, or to their not being parallel, will be reduced in direct proportion to the distance of the lath from the range-finder. This distance should therefore be as great as is consistent with good visibility and ease of observation.

A test for the above difference in length is given on p. 39.

Procedure.—(*a*) *Setting up.*—Place the box at a distance of not less than 300 yards, in such a manner that the lath can be seen from the range-finder. By aligning the short side of the box on one end

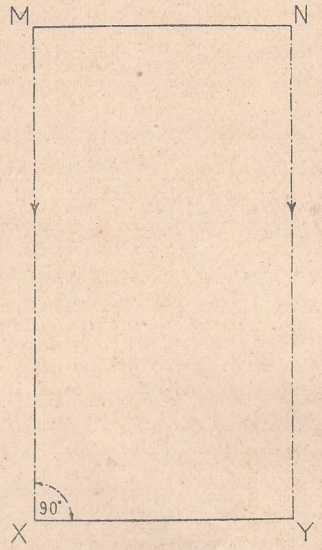


Fig. 19.

of the range-finder when it is directed on the lath, the latter will be set approximately parallel to the range-finder.

(*b*) *Test.*—Take a series of ten observations with the working head, noting the readings + or — of the infinity mark. If the mean reading is greater than $\pm 0{\cdot}5$ of a division, the instrument requires adjustment.

(*c*) *Adjustment.*—Set the range scale to read infinity. Uncover the coincidence adjusting head and use it to take a series of ten observations, noting the readings on the scale of the left-hand window. Set the index line to the mean of these readings and examine the range scale, to see that it has not moved. Cover up the coincidence adjusting head. Adjust for halving if necessary.

Repeat the test as detailed at (*b*). If the mean reading is still greater than 0·5 of a division, the adjustment must be repeated.

C.—Supplementary Tests

The Test of the Astigmatisers.

Procedure.—Choose an object upon which good coincidence can be made with or without the astigmatisers in use.

Take a series of twenty observations alternatively with and without the astigmatisers.

The mean of the ten observations with the astigmatisers should not differ from the mean of the ten without them by more than $8r^2$.

The Test for Difference in Length between the Adjusting Lath and the Base of the Range-finder.

Procedure.—Adjust the range-finder on a natural infinity, preferably by day. Set up the lath at about 200 yards from the range-finder, great care being taken that it is parallel to the base of the instrument.

Take a series of ten observations on the lath.

The Mean Deviation should be less than one division.

Remarks on the above two Supplementary Tests.

Unless the Standard of Consistency is attained, the tests cannot be considered reliable. The Mean Residual of each series should therefore be determined.

If a range-finder fails to pass either of the above tests, the test should be repeated for verification, and if the result is again a failure, the range-finder should be returned to R.A.O.C. Instrument Workshops for repair.

APPENDIX I

CARE AND PRESERVATION OF THE RANGE-FINDER

A.—Transport

The range-finder is designed to withstand service conditions, and is subjected to a rough treatment test before issue.

It is at all times necessary to guard against excessive jolting or a blow to the instrument such as might occur if it were dropped. Such treatment may cause loss of adjustment or even breakage.

When packed in its case it will travel safely in any form of horse or mechanical transport without loss of adjustment. But whenever possible the case should be stowed in a horizontal position with its lid uppermost.

If not in its case, the instrument should be kept in its cover, except during actual range-taking.

B.—Cleaning

(i) *Moisture.*—The range-finder should whenever possible be protected from damp. If used in the rain, it should be wiped dry before replacement in its cover or case.

If interior glass surfaces become filmed with moisture to such an extent as to interfere with range-taking, this should be remedied as detailed in Appendix III.

(ii) *External glass surfaces.*—To avoid loss of light, the windows and eyepieces must always be clean.

Except during range-taking they should be kept covered.

No oil or grease should be allowed to get on them, and they should not be touched with the hands.

Instructions for cleaning when dirty:

(*a*) If free from grease, wipe the glass surfaces with a clean piece of soft linen, silk or tissue; frequently using a fresh portion of the material so as to avoid scratching the glass with grit already collected.*

(*b*) Grease should be cleaned off the glass and edges of the mount with a clean piece of soft linen slightly damped with turpentine or benzine; and the surface afterwards wiped as in (*a*) above. If the turpentine or benzine does not dry off at once, too much has been used, and there is danger of it running round the edges of the glass and damaging the balsam.

---

* Cleaning cloths for glass should be kept under cover so as to remain free from dust, and *not be used for any other purpose.* They should be washed frequently, all soap being carefully rinsed out.

(iii) *External metal surfaces* should be cleaned with a dry cloth. Parts from which the paint or bronzing has worn off may be wiped over with a slightly oily rag before being thus cleaned. The carrier bearing rings should be lubricated. Abrasives or metal polish must not be used.

(iv) *The rubber facepiece* should be periodically removed, washed in warm water and dusted over with French chalk as a preservative.

(v) *Leather parts* should be occasionally oiled.

C.—Re-painting

The range-finder and its case should, when necessary, be re-painted by the Armourer with service colour paint, without stripping the instrument. Leather parts, the web shoulder strap and rubber facepiece will not be painted. The paint will be kept clear of optical and working parts. For painting or touching up the metal portions of the range-finder service colour brushing celluloid paint should be used. For the case, "Paint, Service Colour" (Sec. H. 1) is used.

D.—Storage

The range-finder should be kept in a dry store at as even a temperature as possible. Variations in temperature cause air to be drawn into the instrument, and any moisture present may condense on the inner optical parts. Continued condensation is liable to cause filming which may injure the polished glass surfaces and thus render the instrument unserviceable.

When range-finders are to be stored for long periods in damp tropical climates, they may be taken from their cases and stored in a reasonably airtight chest containing a tray of calcium chloride. The tray should be cleaned out and the chemical broken up or renewed periodically.

The external and internal glass surfaces of range-finders should be inspected periodically (*see* (iv) and (v) of "Procedure," in Appendix II) to ensure that conditions of storage are suitable.

APPENDIX II

EXAMINATION AND TEST OF RANGE-FINDERS

A.—EXAMINATION

This will be carried out periodically in the unit to ensure that the instruments are free from such defects as can be ascertained without dismantling. It will also be carried out at the annual R.A.O.C. inspection of range-finders.

PROCEDURE.

(i) Examine the range-finder to see that it is complete—no missing screws, etc.—and that there are no dents in the outer tube. The revolving rings should move smoothly (Mark III).

(ii) Examine the lath adjusting or the rods and brass sockets to see that no damage or excessive wear has occurred.

(iii) The case, canvas cover and stand should be in a serviceable condition.

(iv) Uncover the end windows and direct the eyepiece towards the light. On looking into (not through) the windows, the optical parts should appear clean and unclouded.

(v) Mount the range-finder on a stand or support. The range-finder body should rotate freely in rings of the carrier. Direct the instrument to the sky, avoiding the sun, and focus the dividing line. The upper and lower fields should appear clean and free from dust or filming.

(vi) Depress the instrument on to a distant object. The images in both fields should be sharply in focus.

(vii) The coincidence adjusting head (Mark III) should move in and out freely, and the coincidence adjusting head (Marks IV and V) and the halving adjusting head (all Marks) should move with decided clicks.

The working head should move freely. It should be possible to feel a *slight* freedom between it and its pinion which is mounted on the inner frame.

The focussing adjustment should work smoothly.

The moderator disc and cover for left eyepiece (Marks IV and V) should rotate freely, and the moderating glasses should be clean.

The astigmatisers should snap in and out with a decided action.

(viii) Set up the lath at 300 yards to 500 yards, *see* p. 38. Adjust the range-finder on the lath. If the coincidence adjusting scale by the left window reads more than twelve divisions from 0, the range-finder should be returned to R.A.O.C. for correction.

(ix) Place the astigmatisers in action. The fields should remain clear and without shadows.

(x) Should the range-finder be found to be defective in any way, minor repairs and cleaning may be carried out by the armourer, if workshop conditions and tools allow. (*See* Appendix III.)

Otherwise the instrument will be returned to R.A.O.C. Detailed testing is carried out by R.A.O.C. after repair.

After repair by the *armourer*, instruments will be tested by range-takers.

B.—Test

Immediately prior to the annual R.A.O.C. inspection of range-finders, testing will be carried out by qualified range-takers under the supervision of an officer who has qualified in the range-finding course at the Military College of Science, or the Small Arms School, Netheravon. The results of this test and any defects or doubtful points will be brought to the notice of the O.M.E.

A range-finder will also be tested at any time that inaccuracy is suspected.

The object of the test is to ascertain that the range-finder when adjusted will give ranges to the expected degree of accuracy (*see* p. 31). The test must be carried out deliberately and only under good conditions of observation.

Procedure.

(i) Select two easy targets, one at about 1,000 yards, and one between 4,000 yards and 6,000 yards. The ranges from the testing position to these points must be known to within r^2 (*see* p. 34).

(ii) Adjust for coincidence on the longer range (*see* p. 34).

(iii) Set up the lath adjusting (*see* p. 38).

The mean deviation of a series of ten readings on the lath should be less than one division.

(iv) Take a series of ten readings on the shorter range. The mean deviation should be less than $8r^2$.

N.B.—The Mean Residual will be calculated to check the consistency of each series taken. If this exceeds $5r^2$, the test is not reliable.

(v) Repeat (iv) with the astigmatisers in action. The mean deviation should be less than $8r^2$.

(vi) " Rough Treatment," which should consist of shaking the instrument thoroughly in the hands, without dropping or jarring, should be applied, and test (iv) repeated.

(vii) Each instrument will be tested as above by two qualified range-takers. If any instrument fails in the above tests, a report will be forwarded to the A.D.O.C. of the command.

Note.—The above are the only tests to be carried out in the unit. Detailed tests to identify particular faults are applied by R.A.O.C. and C.I.A.

APPENDIX III

INSTRUCTIONS FOR SUCH EXTERNAL REPAIRS, DISMANTLING, INTERNAL CLEANING and INTERNAL REPAIRS AS MAY BE CARRIED OUT IN UNITS.

General repairs, not here enumerated, should be carried out by Ordnance Mechanical Engineers or Armament Artificers Instruments in Ordnance Instrument Shops or by C.I.A. Woolwich Arsenal.

The undermentioned operations may be undertaken by Armament Artificers, Armourers and Artificers, R.A., who have passed a course of instruction on the instrument at the Military College of Science since the beginning of 1927, or have been expressly authorized by the O.M.E. to do the work. They should only be undertaken on instruments on the charge of the unit to which the tradesman concerned is attached.

A.—External Repairs

(i) Replacement of missing or damaged screws, handles, end caps, locking plates, etc.

(ii) Cleaning of external glass surfaces, *see* Appendix I.

(iii) Minor repairs to stands, cases and covers.

(iv) Re-painting, *see* Appendix II.

B.—Dismantling

General Instructions.

Dismantling will only be undertaken for the purpose of internal cleaning either when the optical parts are sufficiently dirty or filmed to affect appreciably the identification of targets or the accuracy of range-taking, or for the purpose of a local repair.

As far as is possible, it will only be carried out in a dry, dust-free atmosphere and good working conditions.

For local dismantling and internal cleaning and repairs the following tools and stores are required : instrument maker's screw-driver, holder with eyepiece (for cleaning centre prism combination), turpentine and soft tissue.

The following general precautions should be observed (*see also* Appendix I).

Benches should be clean and covered with paper ; on removal, optical parts should be placed under a cover, care being taken not to film the surfaces in any way, *e.g.*, by breathing on them ; internal parts should be handled with tissue or dust-free linen and not with bare hands ; screw-drivers should be correctly shaped and fit slots in which they are used ; no force should be used.

REMOVAL OF END CAPS AND PENTAGONAL PRISMS.

(*a*) Mark III, remove stop screw and revolve ray shade to expose the screw securing the end cap locking piece, and remove this screw; Marks IV and V, loosen screw securing end cap locking piece.

(*b*) Slide end cap locking piece away from end cap and unscrew the latter. Revolving rings of Mark III instrument may now be removed.

(*c*) The pentagonal prism with mount is levered out by means of a tommy inserted in the hole in the mount, keeping the thumb and finger over the end of the mount to prevent it jumping out.

REMOVAL OF INNER FRAME (after removal of right end cap and pentagonal).

(*a*) Press astigmatiser lever into action (*i.e.* towards body of range-finder) and focussing lever fully down (*i.e.* towards handles).

(*b*) Loosen the two screws securing the working head, turn the plate to clear the screws and remove the working head.

(*c*) Remove the frame suspended screw under the right handle.

(*d*) Gradually incline the range-finder, handles downwards, holding clean tissue or linen to take the inner frame. A slight tap on the open end of the outer tube may be necessary to loosen the inner frame. As soon as it appears give it a slight *clockwise* turn so that the spring plunger on the left supporting ring clears the upper ball ended screw above the right handle.

(*e*) If difficulty is experienced in removing or replacing the inner frame, the inner portion of the astigmatiser lever can first be removed. This is a long screw beneath the screw plug under the left handle. (The outer portion of the astigmatiser lever may be removed after loosening the keep screw just to the right of the left handle). The inner frame may also be eased by very careful manipulation through the working head aperture. Force is not necessary.

REMOVAL OF RIGHT EYEPIECE.

Take off the rubber facepiece and remove countersunk screw on right of eyepiece. Unscrew eyepiece cap, take out small key piece into which the countersunk screw was fixed. Lift out the eyepiece proper with the slotted packing ring and the inner focussing screwed ring complete; if this ring is removed an assembly mark should be scratched on the thread of the eyepiece proper under the lug of the ring. Remove focussing lever. The moderating glasses (and cover ring for left eyepiece of Marks IV and V instruments) can be removed after taking off the ebonite eye cap which is held by three screws covered with wax.

C.—Cleaning of Internal Glass Surfaces

These will be cleaned in accordance with the instructions in Appendix I. No undue pressure should be used. The adjustment of the astigmatisers, for example, may be upset if their mounts are strained.

Instructions for cleaning Centre prism Combination of No. 12 Range-finders, Marks III**, IV** and V †

During this operation very great care should be taken to avoid scratching the soft glass of the prisms. The accuracy of range-taking is largely dependent on a clear-cut dividing line, and may easily be impaired by a scratch near this line.

(*a*) Place inner frame in the holder and reflect light through the object glasses into the centre prism combination. Focus the eyepiece on to the dividing line.

(*b*) With a sharp razor blade cut out a paper spear just thick enough to fit the gap (0·006 inch) between the two prisms. While looking at it through the eyepiece move the spear about in the gap until the upper field is quite clean and free from dust specks. It will be necessary to re-focus the eyepiece on the various parts of the gap.

To remove dust and ragged ends, and thus enable it to enter the gap easily, the spear may be wiped between the folds of a clean linen cloth held in the fingers.

(*c*) With the eyepiece focussed as necessary on the different portions of the lower sloping surface of the upper prism (AC in Fig. 11 (*d*)), wipe this surface very carefully with clean tissue, silk or soft linen. A chisel pointed match-stick well covered with tissue may be used to push a tongue of tissue down towards the dividing line. Repeat (*b*) if necessary.

(*d*) Remove diaphragm plate (held by two small screws between the upper prism and the eyepiece), and wipe the upper sloping surface of the upper prism (BC in Fig. 11 (*d*)).

No attempt should be made to clean the other inaccessible surfaces of the centre prism combination. If loss of light occurs owing to these surfaces becoming very dirty, or if other optical parts cannot be successfully cleaned by the above methods, the range-finder must be returned to R.A.O.C. instrument workshops or C.I.A.

No optical parts will be removed from the inner frame, and no alterations made in the position of any adjusting screws. It is particularly important that the adjusting screws of the centre prism combination and its mount should not be turned.

A report will be made if any instrument at home requires internal cleaning more often than once every year.

† Earlier marks should be returned to C.I.A., Woolwich Arsenal, for this cleaning.

D.—Internal Mechanical Repairs

The internal mechanical actions are not designed for local repair as they should not become damaged in any way. After removal of the left pentagonal, the action of the halving adjustment, and part of the action of the coincidence adjustment (Marks IV and V) can be inspected. Other internal mechanisms are mounted on the inner frame. After this frame has been removed, the action of the astigmatisers can be tested. If they do not snap in and out with a decided action, the springs should be removed and given more set. Apart from this, these mechanical repairs should be confined to ensuring that optical parts are secure in their mounts, tightening loose screws and ensuring that mechanical fits are correct during re-assembly.

If any internal working surface is found to be quite dry, a single drop of instrument oil may be applied to it, all surplus oil being carefully wiped off. The groove inside the milled portion of the working head should be packed with grease when re-assembling so as to minimize the entry of damp into the instrument.

E.—Re-Assembly

Though in general this is the reverse process to dismantling, the following points require special attention.

(i) *Replacing inner frame.*—Set astigmatisers and lever in action and focussing lever downwards. The outer tube should be level when inserting the inner frame, which is given a slight anti-clockwise turn and guided into position by hand. See that the recess for the frame suspension screw is opposite the screw hole, and be sure that the ball end is entering the recess truly when screwing it home. Verify that this screw does not clamp the inner frame. A slight freedom (0·002 inch) of the right end of the inner frame should be felt after the screw is home. Test the action of the astigmatisers before replacing the right pentagonal.

(ii) *Replacing eyepiece.*—Replace outer focussing lever recess upward and opposite the slot in the eyepiece tube. Re-assemble eyepiece, inner focussing lever, and slotted ring and replace the three together in eyepiece tube. Care is necessary to ensure that the eyepiece proper is the right way up (*i.e.* the portion which is internally screwed for the counter cell uppermost). During this assembly the featherway in the eyepiece proper, lug on the focussing screwed ring, slot in the packing ring, and slot in eyepiece tube must all be in line, so that the above lug enters the recess in the focussing lever and the locking key and screw can then be replaced. Replace eyepiece cap and screw.

F.—Test and Adjustment.

After any stripping operation the range-finders should be tested and adjusted as detailed in Appendix II by the range-taker as early as possible.

APPENDIX IV.

PARAGRAPHS OF LIST OF CHANGES AFFECTING THE RANGE-FINDER AND ITS ADJUNCTS PUBLISHED SINCE MARCH, 1912.

Note.—The latest " Marks " quoted below are in all cases current, earlier " Marks " being obsolescent.

RANGE-FINDER, INFANTRY, No. 12.

Date.	*Para. L. of C.*	*Marks introduced.*	*Remarks.*
Mar. 1915	17,106	II	This instrument differs mainly from the Mark V described in Chapter II in that :— i. the centre prism combination consists of 4 prisms cemented together by balsam, two surfaces being silvered. This balsaming and silvering is liable to perish in damp and hot climates. ii. revolving rings are fitted over the end castings. They serve to carry the ray shades and cover the adjusting heads. iii. the coincidence head consists of a spring plunger fitting under a slide. iv. the revolving ring in the cap of the right eyepiece contains blue smoked moderating glasses and a plain glass. The left eyepiece has no revolving ring. A leather eyepiece cover is fitted.
Mar. 1915	17,107	III	This instrument is generally similar to the Mark II.
Oct 1918	21,117	IV	This instrument differs only from a Mark V (described in Chapter II) in that the centre prism combination is of the same type as that in the Mark II (described above).
Aug. 1922	25,151	II*	Mark II modified to Mark II*.
,,	,,	III*	Mark III modified to Mark III*.
,,	,,	IV*	Mark IV modified to Mark IV*. These instruments have been modified by replacing the cemented centre prism combination by one consisting of two solid prisms, without silvering or balsam, and separated by a 0·001-inch air gap.
Aug. 1922	25,151	V	This instrument is fully described in Chapter II.
July 1924	A366	III**	Mark III* modified to Mark III**.

RANGE-FINDER, INFANTRY, No. 12—*continued.*

Date.	*Para. L. of C.*	*Marks introduced.*	*Remarks.*
July 1924	A366	IV**	Mark IV* modified to Mark IV**. These instruments have been modified by increasing the separation of the centre prisms from 0·001-inch to 0·006-inch, and modifying the mount so that local cleaning can be carried out.
Nov. 1931	A6,336	—	Metal seatings for pentagonals. Existing instruments being modified when passing through Woolwich for repair without advancing their Mark.
Aug. 1936	A9,917	—	Centre prism mount fitted with additional bearing screw for adjustment of upper prism. Upper and lower prism bearing screws of steel, centrally bored and fitted with aluminium cores with mushroom heads to butt against prisms. Aluminium insets to prisms.
Aug. 1936	A9,936	III** to V	Clutch plate to be fitted to carrier, as required locally, for use with Mark III stand.

NOTE.—As very few Mark II to II* instruments exist in the Service, reference to them has been omitted elsewhere in this handbook.

CASE No. 12, RANGE-FINDER.

Mar. 1912	15,844	I	Case with 2 testing rods introduced.
Nov. 1913	16,561	—	Case supplied with clip and screwdriver.
,,	16,562	—	Case wood fittings modified.
Mar. 1915	17,102	II	Similar to Mark I case.
Aug. 1918	20,812	III	Mark III case will take Range-finders Marks II to V; Marks I and II cases will not take Range-finders Marks IV and V.
Dec. 1918	21,419	—	Adjusting lines painted on wood of Mark III case omitted.
Nov. 1929	A4,824	I* II* III*	Existing cases to be modified by the fitting of a metal adjusting lath in lieu of the adjusting rods.
		IV	New Mark IV case with lath.
Aug. 1936	A9,935	—	Screwdriver declared obsolete and consequent alteration of nomenclature of case.

COVER No. 12, RANGE-FINDER.

April 1912	15,893	I	
Mar. 1915	17,103	II	
Oct. 1930	A5,521	III	
Aug. 1936	A9,916	III	Addition of bucket, to accommodate the No. 14 Mark III stand, authorized for future manufacture. Marks II and III covers so modified to become Marks II* and III*, respectively.

STAND, INSTRUMENTS, No. 14.

Mar. 1912	15,844	I	
,,	15,845	II	
Aug. 1936	A9,936	III	Introduction of

FROG, No. 14, INSTRUMENT STAND.

Mar. 1912	15,844	I	
July 1935	A9,100	—	Designation altered.

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